European Stock Market Linkages:
The Effect of the Adoption of the Euro as a Single Currency

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Abstract

Daily returns of stock market indices of the major Euro-zone countries of France, Germany, the Netherlands, Italy and Spain are analyzed for the period January 1, 1990 until May 2003. Additionally, the United Kingdom stock market is included in the analysis. The data is divided into two sub-periods to investigate whether the integration of the stock markets increased after the adoption of the Euro. The key issues examined concern how much of the changes in the stock indices in different countries can be attributed to innovations in other markets, and how fast events occurring in one market are transmitted to other markets.

Introduction

Many barriers to the free flow of goods, services, labor and capital among countries have been removed in the last several decades and national economies have become more open. This trend has been more pronounced in the 14 Euro-zone countries in Europe, where a monetary union was implemented on January 1, 1999, with the Euro as the common currency. As a result, companies and investors in the Euro-zone can now make their investment decisions without worrying about exchange-rate risk. European stock markets have also experienced deregulation and integration. Many researchers have examined the linkages among national stock markets but the studies on the effect of the Euro are just beginning. The importance of the subject is clear from a recent keynote address by the president of the European Central Bank (ECB):

> "I believe that the key question for us – public authorities as well as market participants – is how we can contribute to the further integration of financial markets in Europe.[...] The potential gains from monetary union will only be fully realized if remaining barriers to integration of European financial markets are effectively removed. There is considerable evidence that wholesale markets are now much more integrated than before. But integration in securities markets needs to proceed further. Without an integrated European securities market the outcome of the entire process of financial market integration risks falling short of expectations".

Keynote speech by ECB President Jean-Claude Trichet at Deutsche Börse's New Year's Reception 2004,

In a recent study, Bodart and Reding (1999) used conditional volatility models to show that, under the different stages of the European Monetary System, an increase of exchange rate volatility was associated with a decline in the correlation of national bond markets and an exchange rate peg was associated with a reduction of bond price volatility. However, these authors found only weak evidence of the interaction between exchange rate regime and equity market behavior.

This paper uses a vector autoregressive approach to examine the changes in co-movement among the stock market indices of the major Euro-zone countries: France, Germany, the Netherlands, Italy and Spain. Daily returns are analyzed for the period between January 1, 1990 and May 31, 2003. Due to the dominance of the United Kingdom in the European stock market (see Friedman & Shachmurove, 1997), it is included in the analysis even though it is not part of the Euro-zone.

The key issue examined is how much of the change in the stock indices in different countries can be attributed to innovations in other markets, and how fast events occurring in one market are transmitted to other markets. Furthermore, the data is divided into two sub-periods to investigate whether the integration of the stock markets increased after the adoption of the Euro. The next section of this paper discusses the reasons for co-movements among stock markets and why these linkages are thought to have become stronger in recent years. Section 3 presents a short survey of earlier studies of relationships among stock markets. Section 4 describes the framework of the analysis, including the data, the vector autoregressive (VAR) model, unit roots tests and tests for determination of the lag length used in the VAR model. The empirical results are presented in Section 5, followed by the conclusions in Section 6.

Reasons for Co-movements among National Stock Markets

International stock prices are correlated for many reasons. First, the different stock markets may be influenced by the same macroeconomic variables, such as trade linkages among countries or booms and recessions in one country spilling over to other countries. For instance, the rise in an interest rate of one country, caused by high inflation, would lead to immediate fluctuations or interest rate movements in another country. The stock market returns in these two markets would be affected by this potential rise in the interest rate, causing stock prices to fall due to two well-known facts. An increase in interest rate makes it more attractive for investors to move their money away from stocks to other financial instruments such as bonds. In addition, the firms would face higher financial costs on their debt, which leads to a reduced cash flow (Durre & Giot, 2005).

Improved communication technology and the Internet have also increased the speed of dissemination of news across the globe. Another contributing factor to markets' co-movement is the higher degree of cooperation among national governments in recent years and the removal of trade barriers which prevented the flow of goods, services, and capital. This internationalization process has been evident in Europe, where the economic and financial structures have undergone extensive changes in recent years. There has been a rapid development of the financial markets, which has been reinforced since the introduction of the Euro on January 1, 1999. The process of creating and the introduction of the Economic and Monetary Union have contributed to further economic integration and convergence of the economies inside the European Union (Noyer, 2000) in several ways. First, within the Economic and Monetary Union there is a high degree of labor, goods, and capital mobility. Second, there is a common goal to achieve price stability. Third, the introduction of the Euro eliminated exchange rate risk inside the union, and fourth, the macroeconomic policies in the participating countries are coordinated. Finally, the countries have a common monetary policy implemented by the European Central Bank (Apergis & Demopoulos, 1996). These factors are assumed to lead to a higher degree of co-movements among the stock market returns in Euro-zone countries. This assumption is examined in the paper.

Previous Studies on the Interdependence among Stock Markets

Since the work of Grubel in 1968, which pointed out the benefits of international diversification, numerous studies have examined the relationships among national stock markets. Earlier studies by Granger and Morgenstein (1970), Levy and Sarnat (1970), Grubel and Fadner (1971), Agmon (1972) and Ripley (1973) found little or no correlation between national stock markets, based on weekly or monthly data from the 1960s and 1970s. These studies used simple correlation and regression methods. The main conclusions that are found in these papers are that national stock markets are segmented, and that risk reduction through international portfolio diversification is possible. The low degrees of co-movements between the stock markets are explained by barriers of international capital flows, different policies, higher taxes and transaction costs on international capital investments, and a low degree of information about foreign securities.

More recent research utilizes daily stock markets returns. Eun and Shim (1989) investigated the international transmission of stock markets movements using a vector autoregressive system for the period 1980-1985. They found a substantial degree of interdependence among the nine stock markets in their study. Events occurring in the U.S. stock market are quickly transmitted to stock markets in other countries. However, no individual stock market has substantial influence on the U.S. stock market.

Gjerde and Sttem (1995) also use a vector autoregressive model to investigate the dynamic interactions among stock markets. They analyze the period between 1983 and 1994 by using 10 stock market indices. The dynamic interactions among the stock markets are found to be larger than reported by Eun and Shim (1989). The study also found the U.S. stock market to have significant influence on most other markets with the exception of Italy. On the other hand, the stock markets in Europe did not appear to have substantial influence on the world or any of the largest stock markets, such as New York and Tokyo. Furthermore, they found a rapid international transmission mechanism among the different stock markets. Most of the signals from one stock market can influence other markets within the same day, taking into account that stock markets operate in different time zones.

Friedman and Shachmurove (1997) also use a VAR model in their research. They focus solely on European markets for the period January 1988 to December 1994. Their study finds a high degree of interdependence among the larger stock markets in Europe. However, the smaller markets prove to be more independent from other market fluctuations. None of the stock markets is found to be completely unaffected by innovations in other markets. The UK stock market proved to be the leading market in Europe during this period, as opposed to the smaller markets, which seem to have no significant influence on the other markets.

The studies of Becker, Finnerty, and Gupta (1990) and Hassan and Naka (1996) also pointed out the leading role of the U.S. stock market, using correlation analysis and a vector error correction model, respectively. Several researchers have analyzed if the co-movements between stock markets have become stronger after the October 1987 stock market crash. Jeon and Von Furstenberg (1990) analyzed the linkages among the stock markets in Japan, Germany, England and the USA, with the use of a VAR model for the period 1986-1988. By dividing this period into two parts, before and after the stock market crash, they state that for the period before the crash, the stock market returns can be explained based on innovations in the U.S. stock market and from the history of each market. After the crash, the stock market returns were better explained based on previous changes in the foreign stock markets as opposed to their own history, with the exception of Japan. Using causality and co-integration tests, Malliaris and Urrutia (1992) and Arshanapalli and Doukas (1993) also show that the degree of interdependence among stock markets has increased significantly after the 1987 stock market crash.

Malkamäki, et al, (1993) focus on the co-movements among the Scandinavian stock markets. They analyze the stock markets in Sweden, Norway, Denmark and Finland for the period between February 1988 and April 1990, using Granger causality tests. The Swedish stock market has been found to lead the group, whereas the rest show no significant influence over other markets. They also determined that returns on the world stock market, using the world stock index, have a significant leading effect on the Scandinavian stock market returns.

Kanas (1998) analyzes the linkages among the U.S. stock market and six major European stock markets for the period January 1983 to November 1996. The results from this research differ from the findings in the other analyses above. Using three different methodologies to test for co-integration, Kanas discovered that the U.S. stock market does not have pair wise co-integration with any of the European markets. These results imply that there are potential benefits from diversifying in U.S. stocks as well as stocks in European markets. Short-run and long-term links between European and U.S. stock markets are analyzed by Gerrits and Yüce (1999), using a vector error correction model for the period between March 1990 and October 1994. The US market has a long-term influence on the European markets but this is not true in reverse. In a short-term perspective the U.S. market also shows a substantial influence on all other markets. The European stock markets are found to move together. Compared to the studies from the 1960s and 1970s, the more recent studies report a substantial amount of interdependence among national stock markets. This phenomenon can be explained as being the result of the removal of barriers for foreign investment, improvement in information technology, and increased cooperation and trade among countries, along with other reasons.

Methodology

This study aims to examine changes in co-movements among the European stock markets after the introduction of the Euro. By the use of the vector autoregressive approach, stock market indices of the major Euro-zone countries, such as France, Germany, the Netherlands, Italy and Spain are analyzed based on daily returns for the period between January 1, 1990 and May 31, 2003.

Due to the dominance of the United Kingdom in the European stock market, it is also included in the analysis even though it is not part of the Euro-zone.

Data

The data for this study comprise time series of daily stock market indices for six major European stock exchanges: Britain, France, Germany, Italy, the Netherlands and Spain. Morgan Stanley Capital International (MSCI) computed the indices for January 1, 1990 to May 31, 2003. For the methodology of constructing the indices, see `http://www.msci.com/method/index2.html`[1]. The indices are expressed in German Marks for the pre-Euro period and in Euros for the post-Euro period. For each country, daily returns, r_t, are computed as the first differences of the natural logarithms of P_t, the daily close values of the indices, $r_t = (lnp_t - lnp_t - 1)$.

Correlation Analysis

Table 1 shows the correlations among the daily returns for the entire sample period and for the two sub-periods. Note that the EC stock markets are highly correlated as is evidenced by the correlations between the stock markets of France and the Netherlands (0.80), Britain and Netherlands (0.75), France and Spain (0.75), Britain and France (0.74), Germany and France (0.74), and Germany and Netherlands (0.74). Thus, it is apparent that geographical proximity matters. It is also worth noting that the Italian stock market has the lowest correlations with other EC stock markets.

There is a striking difference in correlations between the two sub-periods. For example, the correlation between the UK and France increased from 0.70 to 0.79 in the second sub-period. The correlation between the UK and Germany increased from 0.55 to 0.73, and the correlation between France and Spain increased from 0.69 to 0.83 in the same period.

Each country's series of daily returns (expressed as $r_t = (lnp_t - lnp_t - 1)$) was tested for the presence of a unit root using three alternative tests suggested by Dickey and Fuller (1979), and Phillips and Perron (1998). All these tests reject the assumption of a unit root for all time series considered, implying that the relationships among the various variables analyzed below are not spurious.

Model Choice

The analysis uses a vector autoregression approach, which is described in the appendix. Sims (1980) criticized the simultaneous literature for the ad hoc restrictions needed for identification and for the ad hoc classification of exogenous and endogenous variables in the system. The main differences from the traditional structural (Cowles Commission) method of constructing such econometric models are, according to Charemza and Deadman (1997):

[1] To construct an MSCI Country Index, every listed security in the market is identified. Securities are free float adjusted, classified in accordance with the Global Industry Classification Standard and screened by size and liquidity. MSCI then constructs its indices by targeting for index inclusion 85% of the free float adjusted market capitalization in each industry group, within each country. By targeting 85% of each industry group, the MSCI Country Index captures 85% of the total country market capitalization while it accurately reflects the economic diversity of the market.

1. There is not a prior endogenous division of variables. There are no stock markets that are exogenous. It is not the case that the stock market in Germany influences the stock market in UK, and not the other way around. In a vector autoregressive (VAR) model one does not have to indicate which stock market is exogenous and which is endogenous. However, this is necessary in the structural single-equation or multi equation co-integration models.

2. No zero restrictions are imposed. Using the VAR model one tests how the stock markets influence one another simultaneously. In a simple co-integration approach, one analyzes the direct effect of a one-unit rise in the German stock market on the UK stock market, when all other variables are held constant. This restriction is in fact extremely unrealistic.

3. There is no strict (and prior to modeling) economic theory within which the model is grounded. This follows from the previous points. One does not have to decide which stock market influences another, and no restrictions are imposed. A VAR model requires minimal theoretical demands on the model structure.

Table 1
Correlation Matrix for Sub-Periods

Correlation Matrix 1/1/1990 - 5/31/2003						
	UK	**FRA**	**GER**	**HOL**	**ITA**	**SPA**
UK	1.00	0.74	0.63	0.75	0.58	0.64
FRA	0.74	1.00	0.74	0.80	0.65	0.75
GER	0.63	0.74	1.00	0.74	0.60	0.66
HOL	0.75	0.80	0.74	1.00	0.62	0.69
ITA	0.58	0.65	0.60	0.62	1.00	0.64
SPA	0.64	0.75	0.66	0.69	0.64	1.00

Correlation Matrix 1/1/1990 - 12/31/1998						
	UK	**FRA**	**GER**	**HOL**	**ITA**	**SPA**
UK	1.00	0.70	0.55	0.72	0.50	0.61
FRA	0.70	1.00	0.64	0.71	0.55	0.69
GER	0.55	0.64	1.00	0.67	0.49	0.59
HOL	0.72	0.71	0.67	1.00	0.52	0.63
ITA	0.50	0.55	0.49	0.52	1.00	0.56
SPA	0.61	0.69	0.59	0.63	0.56	1.00

Correlation Matrix 1/1/1999 - 5/31/2003						
	UK	**FRA**	**GER**	**HOL**	**ITA**	**SPA**
UK	1.00	0.79	0.73	0.80	0.72	0.69
FRA	0.79	1.00	0.84	0.88	0.84	0.83
GER	0.73	0.84	1.00	0.80	0.79	0.75
HOL	0.80	0.88	0.80	1.00	0.80	0.78
ITA	0.72	0.84	0.79	0.80	1.00	0.80
SPA	0.69	0.83	0.75	0.78	0.80	1.00

With a VAR model, one only needs to make two specifications (Pindyck & Rubinfeld, 1998, p. 400):

1. The variables (endogenous and exogenous) that are believed to interact should be included as a part of the economic system one is trying to model.

2. The largest number of lags needed to capture most of the effects that the variables have on each other.

The two most common methods used in the recent analysis of linkages among stock markets are the vector autoregressive model and a vector error correction model. Since the aim of this paper is to analyze linkages among European stock markets, we chose to use the VAR model because it was found to be more appropriate for studying dynamic inter-linkages of stock markets. Since the main concern of investors is the stock market returns and not some arbitrary defined index levels, we believe that the relevant co-integration is between returns and not the levels (see for example Friedman and Shachmurove, 1997 and Gjerde and Sttem, 1995).

One weakness of the VAR model is the importance of ordering the variables. It is important which stock market is called y_1, which is called y_2, and so on. The order of the variables has to be specified by the analyst, since no statistical methods exist that can determine the ordering of the variables. In an impulse response analysis the first variable must therefore be the only one with a potential immediate impact on all other variables. The second could influence the remaining variables, but it would have no potential immediate impact on the first variable. Another problem is the potential for the model to be incomplete. When important variables are omitted from the system, this could have an impact on the results, since it makes the impulse responses less valuable for structural interpretations.

Determination of the Lag-Length

An important part of the analysis is to determine the appropriate lag structure in the VAR model. Standard recommendation for the selection of the appropriate lag length is to choose the number of lags to be long enough to ensure that the residuals are white noise, but not too long, since the estimates can become imprecise. The lag length is therefore often selected somewhat arbitrarily. The number of lags was chosen based on three tests: The Likelihood Ratio tests (Sims, 1972), the Information Criteria suggested by Akaike (1973) and by Schwarz (1968). While the Akaike and Schwarz tests indicated that as few as two lagged daily returns may be sufficient, the Sims test suggested that 15 lags are needed. A lag length of 15 ensures that all the dynamics in the data is captured and is used in this analysis. (Eun and Shim [1989] and Friedman and Shachmurove [1997] also used 15 lags.)

Empirical Results

Table 2 presents the correlation matrix of residual returns. These residuals are the part of returns not explained by past returns of all six stock markets. The larger stock markets in Europe have high correlation values, a fact which will affect the inferences from the variance decomposition below. Like the correlation of returns, the correlation of residuals also increased following the introduction of the Euro.

Table 3 presents the results of the forecast error variance decomposition for 5-day, 10-day, and 15-day-ahead horizons for three periods. The first part consists of the entire sample, namely from January 1, 1990 until the end of the sample, May 31, 2003. The remaining parts are two sub-periods: Period I is before the introduction of the Euro, from January 1, 1990 until December 31, 1998, and Period II is after the introduction of the Euro, from January 1, 1999 until May 31, 2003. The Cholesky ordering reported here is as follows: UK, Germany, France, Holland, Italy and Spain where the stock markets were ranked by market capitalization.

Table 2
Correlation Matrices of Residual Returns

Correlation Matrix of Residuals 12/31/1990 - 5/31/2003						
	UK	**FRA**	**GER**	**HOL**	**ITA**	**SPA**
UK	1.000	0.738	0.636	0.750	0.577	0.640
FRA	0.738	1.000	0.751	0.793	0.653	0.749
GER	0.636	0.751	1.000	0.747	0.597	0.665
HOL	0.750	0.793	0.747	1.000	0.615	0.690
ITA	0.577	0.653	0.597	0.615	1.000	0.636
SPA	0.640	0.749	0.665	0.690	0.636	1.000

Correlation Matrix of Residuals 12/31/1990 - 12/31/1998						
	UK	**FRA**	**GER**	**HOL**	**ITA**	**SPA**
UK	1.000	0.696	0.556	0.711	0.505	0.608
FRA	0.696	1.000	0.651	0.713	0.551	0.695
GER	0.556	0.651	1.000	0.675	0.487	0.596
HOL	0.711	0.713	0.675	1.000	0.515	0.625
ITA	0.505	0.551	0.487	0.515	1.000	0.549
SPA	0.608	0.695	0.596	0.625	0.549	1.000

Correlation Matrix of Residuals 12/31/1998 - 5/31/2003						
	UK	**FRA**	**GER**	**HOL**	**ITA**	**SPA**
UK	1.000	0.772	0.719	0.776	0.699	0.659
FRA	0.772	1.000	0.845	0.853	0.838	0.811
GER	0.719	0.845	1.000	0.792	0.774	0.737
HOL	0.776	0.853	0.792	1.000	0.783	0.754
ITA	0.699	0.838	0.774	0.783	1.000	0.786
SPA	0.659	0.811	0.737	0.754	0.786	1.000

Table 3
Results from the Variance Decomposition

Table 3a: Markets Influences Explained during 01/01/1990 - 05/31/2003								
	Period	UK	GER	FRA	HOL	ITA	SPA	*AOM
UK	5	98.99	0.25	0.09	0.42	0.12	0.13	1.01
	10	97.35	0.80	0.33	0.67	0.33	0.51	2.65
	15	96.49	0.98	0.44	0.91	0.44	0.74	3.51
GER	5	39.70	58.96	0.97	0.09	0.11	0.19	41.04
	10	39.72	58.03	1.25	0.40	0.22	0.38	41.07
	15	39.42	57.77	1.41	0.55	0.32	0.53	42.23
FRA	5	53.94	13.67	31.80	0.34	0.19	0.07	68.20
	10	53.46	13.74	31.24	0.79	0.33	0.44	68.76
	15	53.08	13.93	30.99	0.93	0.42	0.66	69.01
HOL	5	55.73	12.42	3.86	27.81	0.13	0.04	72.19
	10	55.15	12.49	4.06	27.50	0.32	0.48	72.50
	15	54.57	12.56	4.13	27.56	0.37	0.81	72.44
ITA	5	32.99	8.88	4.52	0.85	52.73	0.03	42.27
	10	32.83	8.91	4.67	1.37	52.13	0.10	47.87
	15	32.58	9.18	4.66	1.39	51.66	0.52	48.34
SPA	5	40.49	11.55	7.41	0.81	2.26	37.47	62.53
	10	40.33	11.67	7.38	1.37	2.33	36.91	63.09
	15	40.06	11.97	7.46	1.50	2.44	36.57	63.43

Table 3b: Markets Influences Explained during 01/01/1990 - 12/31/1998								
	Period	UK	GER	FRA	HOL	ITA	SPA	*AOM
UK	5	98.15	0.84	0.09	0.60	0.11	0.21	1.85
	10	96.88	1.19	0.39	0.63	0.62	0.30	3.12
	15	95.92	1.31	0.45	0.78	0.73	0.80	4.08
GER	5	29.67	66.95	2.50	0.22	0.18	0.48	33.05
	10	29.47	65.95	3.16	0.42	0.44	0.55	34.05
	15	29.63	65.28	3.13	0.49	0.59	0.88	34.72
FRA	5	47.83	10.99	40.73	0.17	0.25	0.03	59.27
	10	47.32	11.14	40.34	0.29	0.48	0.43	59.66
	15	47.07	11.24	39.90	0.40	0.60	0.79	60.10
HOL	5	49.59	12.15	2.90	35.06	0.18	0.12	64.94
	10	49.09	12.16	3.34	34.70	0.52	0.19	65.30
	15	48.66	12.24	3.36	34.39	0.64	0.70	65.61
ITA	5	24.87	6.28	4.06	0.96	63.67	0.16	36.33
	10	25.08	6.24	4.18	1.48	62.74	0.28	37.36
	15	25.15	6.43	4.13	1.70	61.77	0.82	38.23
SPA	5	35.96	10.59	7.34	0.75	2.27	43.09	56.91
	10	35.65	10.78	7.35	1.36	2.42	42.44	57.56
	15	35.66	10.92	7.36	1.47	2.55	42.04	57.96

After Introduction of Euro								
Table 3c: Markets Influences Explained during 12/31/1998 - 5/31/2003								
	Period	**UK**	**GER**	**FRA**	**HOL**	**ITA**	**SPA**	***AOM**
	5	98.10	0.63	0.21	0.50	0.43	0.13	1.90
UK	10	93.53	1.90	1.24	1.31	0.55	1.47	6.47
	15	91.22	2.40	1.72	2.03	0.81	1.82	8.78
	5	52.37	46.39	0.15	0.28	0.62	0.19	53.61
GER	10	52.37	43.85	1.42	0.59	0.74	1.02	56.15
	15	50.65	43.20	2.26	0.93	1.03	1.93	56.80
	5	59.60	17.21	21.24	0.78	0.94	0.23	78.26
FRA	10	57.99	16.85	20.58	1.91	1.07	1.60	79.42
	15	56.37	17.12	20.35	2.56	1.21	2.39	79.65
	5	60.34	12.19	5.80	20.50	0.72	0.46	79.50
HOL	10	58.51	12.13	6.29	19.95	1.11	2.01	80.05
	15	56.58	12.44	6.54	20.31	1.21	2.92	79.69
	5	50.12	14.97	7.62	1.14	25.84	0.31	74.16
ITA	10	45.49	14.62	7.81	1.62	24.88	1.48	75.12
	15	48.45	15.08	8.11	1.89	24.31	2.17	75.69
	5	45.19	14.32	8.20	1.45	2.73	28.11	71.89
SPA	10	44.37	14.25	8.98	2.27	2.84	27.29	72.71
	15	43.16	14.55	9.41	2.78	2.87	27.33	72.77

Cholesky Ordering: UK GER FRA HOL ITA SPA
Standard Errors: Monte Carlo (100 repetitions)

*AOM: All Other Markets. Denotes the percentage of forecast error variance of the market of the first column explained collectively by all the other markets.

For all periods of analysis, within a time horizon of 5, 10, and 15 days, Holland is the most open market, being influenced by about 72% from all other markets excluding its own market. The next most open market throughout the period of the study is France (69%) and then Spain (about 63%) and Italy (48%). The leading market in Europe is the UK, where about 40% of a one-standard deviation shock to Germany and to Spain is explained by the UK stock market returns. The UK market explains about 54% of the French and the Netherlands stock market returns. As Friedman and Shachmurove (1997) have found, the ordering between France and Germany may influence the results reported here, increasing the openness of Germany's stock market to outside innovations and decreasing the openness of the French stock market.

Comparing the variance decompositions for the first and the second periods, it is clear that the European stock markets have become more integrated after the introduction of the Euro. For example, whereas the UK stock market was influenced only by 4% of other markets in the first period, this number more than doubled in the second period. The results for all other markets in the study are indeed remarkable. Germany is now being influenced by 57%; compared with only 35% in the first period. The influence other markets now have on France has increased from 60% to 80%. The Netherlands market, which was already an open market, was influenced by 65% in the pre-Euro period and is now being influenced as much as the French stock market. Moreover, after the introduction of the Euro, the influence on the relatively isolated Italian market increased to 76%, after being preceded by only 38% in the first period. Another remarkable change occurred in the Spanish market; it is now explained by the influence of the other markets by 73% as compared to 58% before the introduction of the Euro.

Table 4
Accumulated Responses of a One Standard Deviation shock Cholesky Ordering based on Monte Carlo (100 repititions) Simulations.

Table 4a: Before Introduction of Euro							
	Period	**UK**	**GER**	**FRA**	**HOL**	**ITA**	**SPA**
	1	1.11%	0.00%	0.00%	0.00%	0.00%	0.00%
UK	2	1.03%	−0.06%	−0.02%	−0.07%	0.01%	0.03%
	3	1.06%	−0.13%	−0.01%	−0.10%	0.04%	0.06%
	1	0.65%	0.98%	0.00%	0.00%	0.00%	0.00%
GER	2	0.72%	0.86%	0.19%	−0.02%	0.04%	0.07%
	3	0.72%	0.79%	0.21%	−0.06%	0.06%	0.08%
	1	0.84%	0.38%	0.78%	0.00%	0.00%	0.00%
FRA	2	0.79%	0.32%	0.80%	−0.05%	0.02%	0.00%
	3	0.76%	0.21%	0.85%	−0.05%	0.07%	−0.01%
	1	0.75%	0.35%	0.18%	0.62%	0.00%	0.00%
HOL	2	0.71%	0.29%	0.20%	0.55%	0.02%	0.03%
	3	0.71%	0.20%	0.21%	0.50%	0.05%	0.03%
	1	0.78%	0.38%	0.29%	0.11%	1.24%	0.00%
ITA	2	0.81%	0.40%	0.39%	0.01%	1.40%	0.04%
	3	0.79%	0.31%	0.42%	0.00%	1.44%	0.07%
	1	0.83%	0.42%	0.36%	0.09%	0.19%	0.90%
SPA	2	0.80%	0.41%	0.42%	0.03%	0.23%	1.00%
	3	0.77%	0.27%	0.45%	0.00%	0.29%	1.03%

Table 4b: After Introduction of Euro							
	Period	**UK**	**GER**	**FRA**	**HOL**	**ITA**	**SPA**
	1	1.42%	0.00%	0.00%	0.00%	0.00%	0.00%
UK	2	1.37%	0.11%	0.00%	−0.04%	−0.01%	0.00%
	3	1.26%	0.13%	0.03%	−0.04%	0.07%	0.00%
	1	1.36%	1.28%	0.00%	0.00%	0.00%	0.00%
GER	2	1.28%	1.25%	0.03%	0.00%	0.01%	0.01%
	3	1.25%	1.29%	0.05%	0.00%	0.13%	0.05%
	1	1.26%	0.65%	0.74%	0.00%	0.00%	0.00%
FRA	2	1.27%	0.82%	0.63%	−0.05%	−0.01%	−0.06%
	3	1.19%	0.80%	0.60%	−0.05%	0.12%	−0.08%
	1	1.28%	0.54%	0.38%	0.73%	0.00%	0.00%
HOL	2	1.29%	0.71%	0.32%	0.63%	−0.02%	−0.08%
	3	1.21%	0.71%	0.30%	0.64%	0.11%	−0.11%
	1	1.04%	0.56%	0.40%	0.11%	0.74%	0.00%
ITA	2	1.01%	0.63%	0.38%	0.09%	0.68%	−0.05%
	3	0.97%	0.70%	0.36%	0.07%	0.75%	−0.07%
	1	1.08%	0.60%	0.45%	0.14%	0.25%	0.85%
SPA	2	1.05%	0.72%	0.38%	0.12%	0.24%	1.85%
	3	0.94%	0.71%	0.39%	0.13%	0.32%	1.82%

Table 4 presents the simulation results of the accumulated responses of a one-standard-deviation shock, using Cholesky ordering based on Monte Carlo with 100 repetitions. The ordering is again as in Table 3. Table 4 presents these accumulated responses for the two sub-periods, Period I and Period II, and only for the first three days after the introduction of the shocks. For example, the effect of the UK market on the German market increased from 0.72% before the introduction of the Euro to 1.25% after the Euro's, introduction, a 74% increase. The accumulated effect of the German market on the French market rose from 0.21% to 0.80%. In general, one can see the same pattern emerging; more interdependence and a higher degree of inter-linkages among the developing stock markets of Europe.

Conclusions

Using a vector autoregressive model this paper analyzes causal relations and dynamic interactions among major Euro zone stock markets. The data covers a period with large changes in the European economies, with the progress toward and the introduction of the Economic and Monetary Union. The findings in this study indicate that the co-movements of the European stock markets have increased after the introduction of the Euro. This is especially pronounced for the stock markets in Germany, France, Holland, Italy and Spain, the five Euro zone countries in the analysis. Compared to previous studies, the results also indicate substantial increased international financial integration. This implies that the benefits of international diversification within the Euro zone stock markets have decreased considerably over recent years. Some interesting results are found for single countries. For instance, the Italian stock market is found to be linked to the other European markets to a much higher extent than was found in previous studies. Finally, the time paths of impulse responses to a shock in the stock market in the UK, the only country in the study that kept its national currency, shows a rapid transmission of information among stock markets in Europe. This supports the hypothesis of international stock markets efficiency.

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Appendix

The VAR Model

The VAR model assumes that each variable depends on its own past values and on the past values of all other variables in the system of equations. The model can be expressed as

$$(A.1) \qquad Y_t = X_t \cdot \beta + \sum_{i=1}^{L} A_i \cdot Y_{t-i} + U_t$$

$$(A.2) \qquad E[U_t \cdot U_t = \psi$$

where Y_t is an $n \times 1$ vector of daily stock market returns, $X_t \times \beta$ is the deterministic component of Y_t. In the present application X_t is a vector of ones. The term Ut is an $n \times 1$ vector of serially uncorrelated errors, As is an $n \times n$ matrix of coefficients and L is the number of lags. The moving average representation (MAR) of the VAR model can be written as

$$(A.3) \qquad Y_t = X_t \cdot \beta + \sum_{i=0}^{\infty} \cdot E_{t-i}$$

where, E_{t-s} for $s = 0, \cdots, \infty$ is an n-variate white noise process, and E_t and E_s are uncorrelated for $t \neq s$, (Sims 1972).

There are many equivalent representations for this model. For any non-singular matrix G, the matrix of coefficients $\mathrm{B_s}$ can be replaced by $\mathrm{B_s} \cdot \mathrm{G}$ and E by $\mathrm{G} - 1 \cdot \mathrm{E}$. A particular version is obtained by choosing some normalization.

If $\mathrm{B_0}$ is normalized to be the identity matrix, each component of $\mathrm{E_t}$ is the error that results from the one step ahead forecast of the corresponding components of $\mathrm{Y_t}$. These are the non-orthogonal innovations in the components of Y because, in general, the covariance matrix $\Phi = \mathrm{E}[\mathrm{E_t} \cdot \mathrm{E}'_t]$ is not diagonal.

It is more useful to look at the moving average representation of the system with orthogonalized innovations. If any matrix G is constructed to satisfy

$$(A.4) \qquad G^{-1} \cdot \Phi \cdot G^{-1} = I$$

then the new innovations $\mathrm{v_t} = \mathrm{E_t} \cdot \mathrm{G}^{-1}$ satisfy

$$E[v(t) \cdot v(t)'] = I$$

These orthogonalized innovations have the important property that they are uncorrelated across time and across equations. Such a matrix G can be any solution which satisfies the condition that $GG' = \Phi$. The problem is that there are many such factorizations of a positive definite matrix Φ.

The literature on time-series suggests a number of ways to accomplish the factorization of Φ. Some techniques are based on the Choleski factorization, where G is restricted to be a lower triangular matrix. Other techniques are based on orthogonalization using the eigenvalues. Sims (1980) suggested imposing restrictions on the Φ matrix by constraining it to be a lower triangular matrix. In general, the moving average model (A.4) is diagonalized as follows:

$$(A.6) \qquad BU(t) = V(t)$$

and

$$(A.7) \qquad E[V(t) \cdot V(t)'] = D$$

where D is a diagonal matrix. The model can be estimated by minimizing the log likelihood function with respect to the free parameters in the matrices, A and D in equation (A.8).

$$(A.8) \qquad -2 \log |A| + \log |D| + \text{trace} \, (D^{-1} \cdot A \cdot S \cdot A')$$

where S is the sample covariance matrix of residuals, and A is the coefficients matrix of (A.1).

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